ADVANCED CO_2 CYCLE POWER GENERATION

QUARTERLY TECHNICAL PROGRESS REPORT
JULY 1, 2003 THROUGH SEPTEMBER 2003

By

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Disclaimer

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Abstract

Research is being conducted under United States Department of Energy (DOE) Contract DE-FC26-02NT41621 to develop a conceptual design and determine the performance characteristics of a new IGCC plant configuration that facilitates CO_2 removal for sequestration. This new configuration will be designed to achieve CO_2 sequestration without the need for water gas shifting and CO_2 separation, and may eliminate the need for a separate sequestration compressor.

This research introduces a novel concept of using CO_2 as a working fluid for an advanced coal gasification based power generation system, where it generates power with high system efficiency while concentrating CO_2 for sequestration. This project supports the DOE research objective of development of concepts for the capture and storage of CO_2.

Table of Contents

1. Executive Summary

Project Overview

The linkage between global climate change and emission of greenhouse gases such as carbon dioxide (CO_2) is well documented. Modern pulverized coal-fired power plants are some of the largest single point emitters of CO_2. To assure continued U.S. power generation from its abundant domestic coal resources, new coal combustion technologies must be developed to meet future emissions standards, especially CO_2 sequestration.

This project will develop a conceptual design to determine the performance characteristics of a new IGCC plant configuration that facilitates CO_2 removal for sequestration without the need for water gas shifting and CO_2 separation and may eliminate the need for a separate sequestration compressor. The plant will introduce a novel concept of using CO_2 as a working fluid for an advanced coal gasification based power generation system, where it generates power with high system efficiency while concentrating CO_2 for sequestration. This project supports the DOE research objective of development of concepts for the capture and storage of CO_2.

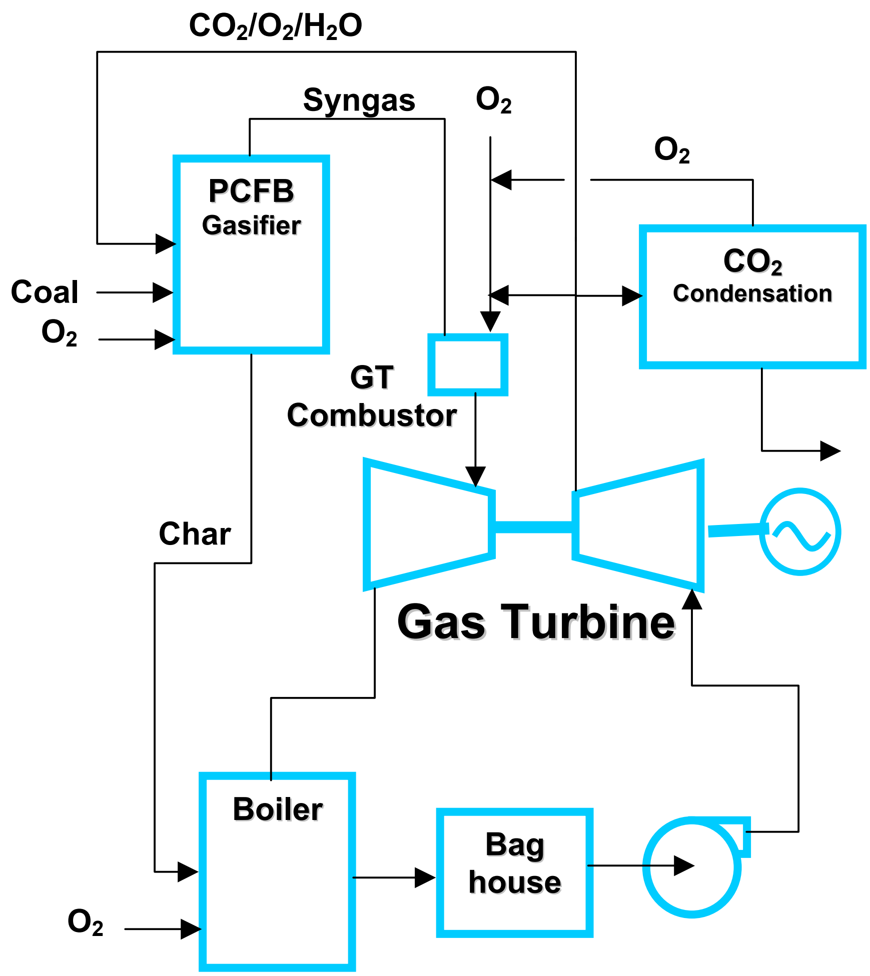
A published study[1]* has shown that CO_2 removal/sequestration systems applied to the back end of a pulverized coal-fired plant can reduce its efficiency by up to 11 points with a resulting $30 per ton CO_2 removal cost. For oxygen-blown IGCC plants, carbon monoxide can be water gas shifted to hydrogen and CO_2 upstream of the gas turbine. The CO_2 can then be separated and concentrated by absorption and stripping or by membranes and then compressed for sequestration. This process is energy intensive, costly, and lowers system efficiency due to the energy losses associated with shifting. (Because the lower heating value (LHV) of hydrogen is less than carbon monoxide on a per mole basis, 15% of the LHV is lost when carbon monoxide is shifted to hydrogen. Therefore, more syngas needs to be generated from gasification to compensate for the shift loss. The low-grade heat from the shift reaction contributes to system losses.) An efficiency loss of 6% with a CO_2 removal cost of $15 per ton is estimated for such an IGCC plant.

The proposed advanced gasification system avoids these problems by using a mixture of CO_2 recycled from the gas turbine exhaust together with oxygen as the working fluid; this facilitates straightforward concentration of CO_2 at high pressure without a shift reaction and, depending upon the required pipeline pressure, may eliminate the need for a separate compressor for sequestration. Any excess oxygen in the gas turbine exhaust is recycled along with the CO_2 back to the gasifier, thus minimizing oxygen usage. The process eliminates the need for CO_2 shifting, absorption, and stripping allowing direct collection of CO_2 at the gas turbine compressor discharge pressure. This results in a simpler CO_2 collection process than conventional oxygen-blown IGCC systems while providing additional advantages of a lower cost and a minimal loss in efficiency.

* numbers in brackets indicate reference

A simplified schematic of the process is shown below in Figure 1.

Figure 1. Process Schematic



Progress During the Quarter (July 1 through September 2003)

The conclusion of Task 1 – Cycle Analysis during the previous quarter verified the performance and emissions benefits of the proposed cycle and highlighted some of the technological issues.

Cycle analyses revealed that, due to certain aspects of the properties of CO2 as a compressible working fluid (mainly the density and the specific heat ratio), the best efficiency for the cycle could be obtained with a special turbine that has an inlet temperature of 2200 F and a compression ratio of 49.

Since this is not currently a commercially available turbine, an investigation of the sensitivity of cycle efficiency to turbine inlet pressure and temperature was deemed necessary. ASPEN simulations are currently being conducted to determine this sensitivity.

Task 2 – Gasifier and Boiler Design was initiated with current emphasis on gasifier design. The turbine inlet pressure has implications on gasifier design, both in terms of sizing the unit for a desired process velocity and residence time, and in terms of providing adequate structural integrity. The impact of turbine inlet pressure on gasifier design and the cost implications of the same will be investigated.

2. Experimental

This work is a conceptual study and does not employ any experimental methods.

3. Results and Discussion

Preliminary cycle analysis indicates that the proposed CO_2 cycle will require the working medium to be compressed to a higher pressure than that of the current air-blown gasification combined cycle technologies. Increasing the moisture content in the working medium can reduce the inlet pressure requirement. A mixture of 70% CO_2 and 30% H_2O would require a gas mixture inlet pressure of about 800 psia.

Alternatively, lower turbine inlet pressures can be possible by diluting the products of syngas combustion to a lower temperature (~1600 F). This will lower the capital and operating costs of the plant but at a cost to net cycle efficiency. Further cycle analysis is being done to better understand this trade-off.

4. Conclusion

No technical project conclusions are currently available.

5. References

1. "Evaluation of Innovative Fossil Cycles Incorporating CO_2 Removal", M. De Lallo et al, Parsons Energy and Chemical Group. Presented at 2000 Gasification Technologies Conference, San Francisco, CA, October 8-11, 2000.